Bellocchi, Alberto, Ritchie, Stephen M., Tobin, Kenneth, King, Donna T., Sandhu, Maryam, & Henderson, Senka
(2014)
Emotional climate and high quality learning experiences in science teacher education.
Journal of Research in Science Teaching, *51*(10), pp. 1301-1325.

http://doi.org/10.1002/tea.21170

Emotional Climate and High Quality Learning Experiences in Science Teacher Education

Alberto Bellocchi[1], Stephen M. Ritchie[2], Kenneth Tobin[3], Donna King[1], Maryam Sandhu[1], Senka Henderson[1]
[1]Queensland University of Technology
[2]Murdoch University
[3]City University of New York

Author Note

Alberto Bellocchi, Faculty of Education, School of Curriculum, Queensland University of Technology; Stephen M. Ritchie, School of Education, Murdoch University; Kenneth Tobin, The Graduate Centre, City University of New York; Donna King, Maryam Sandhu, and Senka Henderson, Faculty of Education, School of Curriculum, Queensland University of Technology.

The Australian Research Council Discovery Grant, contract grant number: DP120100369, supported this research. Any opinions, findings, and conclusions or recommendations expressed in this article are those of the authors and do not necessarily reflect the views of the Australian Research Council.

Correspondence concerning this article should be addressed to Dr. Alberto Bellocchi, Faculty of Education, School of Curriculum, Queensland University of Technology, Kelvin Grove, Queensland, Australia, 4059.
Contact: alberto.bellocchi@qut.edu.au

Abstract

The role of emotion during learning encounters in science teacher education is under-researched and under-theorized. In this case study we explore the emotional climates, that is, the collective states of emotional arousal, of a preservice secondary science education class to illuminate practice for producing and reproducing high quality learning experiences for preservice science teachers. Theories related to the sociology of emotions informed our analyses from data sources such as preservice teachers' perceptions of the emotional climate of their class, emotional facial expressions, classroom conversations, and cogenerative dialogue. The major outcome from our analyses was that even though preservice teachers reported high positive emotional climate during the professor's science demonstrations, they also valued the professor's in the moment reflections on her teaching that were associated with low emotional climate ratings. We co-relate emotional climate data and preservice teachers' comments during cogenerative dialogue to expand our understanding of high quality experiences and emotional climate in science teacher education. Our study also contributes refinements to research perspectives on emotional climate.

Keywords: science teacher education, preservice education, emotions, emotional climate, quality

Emotional Climate and High Quality Learning Experiences in Science Teacher Education

Despite a longstanding interest in research on the effectiveness of science-teacher education programs (e.g., James, 1971), few studies have investigated the synergy between emotions, emotional climate and the quality of science teacher education in university classes. Briefly, emotional climate refers to the collective experience of emotional arousal that develops among groups of people. James' (1971) work provides one example of early interest on the role of general affective states (i.e., attitudes) in preservice science teacher education. Her study explored whether three different supervisory models used in conjunction with practicum had any effect on preservice science teachers' attitudes towards a desirable teaching strategy (i.e., an inductive-indirect teaching technique). Relationships between teacher attitudes and the teaching technique were established through statistical analyses of pre- and post-test data from questionnaires. The group of teachers who received traditional visits from a university supervisor supplemented by self-evaluation sessions using video data of their teaching showed the largest change towards the desired teaching practice. Concomitantly, there were positive changes in science teachers' attitudes towards the teaching strategy in this experimental group. More recently, beginning university professors' use of student-centered or teacher-centered teaching practices has been linked to experiences of positive and negative emotions respectively (Trigwell, 2012). As professors change their teaching practices to more student-focused ones, they experience positive emotions that in turn encourage them to reproduce these pedagogies in future classes. From a student perspective, studies grounded in psychological frameworks have connected emotions to various dimensions of student learning including their motivation, learning strategies, learning outcomes, and achievement (Pekrun & Stephens, 2010). Together, the findings reported by James (1971), Pekrun and Stephens (2010), and Trigwell (2012) are suggestive of potential connections between classroom emotions and the quality of classroom experiences. However, emotional experiences in higher education studies tended to be measured indirectly using questionnaires limiting our understanding of the role of classroom interactions on the production of collective emotional arousal and high quality learning experiences. We attend to the connections between collective emotions, classroom interactions, and the quality of learning experiences directly in our naturalistic study of Donna's (i.e., the professor and fourth author) preservice secondary science teacher education class.

This research is warranted because the general quality of education is related to classroom emotions (Schutz, Aultman, & Williams-Johnson, 2009), yet few studies have focused on the emotional experiences of university students in naturally occurring interactions especially through a combination of indirect and direct methods (Pekrun & Stephens, 2010). More specifically, Schutz et al. (2009) asserted that classroom emotions have considerable implications for school climate. For example, positive emotions and positive classroom climates are desirable because they mediate the development of positive attitudes towards teaching (Tok, 2011) and learning (Schutz et al., 2009). Data on the quality of teacher education programs have tended to come from large-scale surveys of recent graduates, teachers, and school principals, which has meant that the voices and in-the-moment emotional experiences of students are generally understudied. Furthermore, the main theoretical orientations to research have been informed by psychological rather than sociological perspectives. Within a sociological framework of emotions, we employ fine-grained methods for unveiling students' perceptions of high quality learning experiences, classroom emotional climate, and in-the-moment emotional arousal.

Issues of Quality in Education

Although relationships have been established between student outcomes and teaching quality, precise notions of what constitutes "quality" are framed by "different values, sociocultural norms, and aims" (Goodwin, 2008, p. 399) without reaching a unified definition of the construct (Segers & Dochy, 1996). We adopted Newton's (2010) pragmatic position that quality is "stakeholder-relative" so we listened to the voices of preservice science teachers in deciding what they perceived to be high quality experiences in their science education methods course. A vignette from one classroom episode in our study is used to illustrate a high quality learning experience as perceived by the students. The teaching episode took place during one of Donna's regular lessons on science pedagogy for preservice science teachers in their second year of an undergraduate education program.

Vignette- A High Quality Classroom Experience

> Donna modeled a discrepant event[1] teaching technique to her preservice students. As students observed the counter-intuitive phenomenon unfolding, class interactions were characterized by the buzz of lively conversation, smiling, laughter and expression of positive emotions. Students expressed surprise and wonder at the phenomenon by exclaiming "awesome" and "wow." (Field notes, Video file, 26-3-2012)

Episodes such as the one in the vignette drew our attention to previous research that has related high-quality science teacher education with the professor's modeling of professional knowledge and skills (i.e., presenting science demonstrations; Kessinger, 2009), or *practical wisdom* (Feldman, 1997). In the vignette, the professor's modeling of these practices reflects pedagogical approaches supported by educational research, and accepted best practices. Specifically, Donna modeled the discrepant event technique (Nussbaum & Novick, 1982) for the preservice teachers. This kind of modeling provides preservice science teachers with a clear example of effective teaching practice using discrepant events (see Appleton, 1995) that is considered *best practice* when teaching science concepts and inquiry processes. We return to the vignette throughout the article to frame relevant literature and aspects of the study design. Our initial observations of episodes like the one in the vignette ignited our interest in what potential relationships might exist between students' perceptions of emotional climate, emotions and the quality of classroom learning experiences.

Conceptual Tools for Investigating EC and Emotion in Science Teacher Education

Researchers in education psychology and science education have begun to develop classifications of context-specific *academic emotions* (i.e., relating to studying or assessment results; Pekrun & Stephens, 2010) and sub-categories such as *topic emotions* (e.g., emotions experienced in specific science topics; Sinatra, Broughton, & Lombardi, 2014). These approaches allow understandings about the ways students experience positive academic emotions towards a subject such as physics, but may also experience negative emotions towards a topic in that subject such as nuclear energy. Attention in these approaches has been on the object that students' emotions are directed towards (i.e., doing an exam, learning a topic). We are also interested in what activities preservice teachers' emotions are directed at, however, our main focus is on classroom interactions associated with different topics and learning activities. For this reason, we draw on sociological theories of emotions that attend to emotions in interaction. Beginning with differentiating emotions from other experiences such as feelings and moods, we consider the types of emotions common to human experience in the next section.

A Sociological Perspective on Emotion

Emotions are biological and cultural processes involving physiological states of arousal (Turner, 2007). Although there is no consensus on a definition of emotion in the literature, Turner's (2007) usage is compatible with definitions used in other fields of educational research (e.g., Pekrun & Stephens, 2010). Emotions are culturally delineated

[1] A discrepant event is a counter-intuitive phenomenon that is typically presented with the intent of generating cognitive dissonance for students. Typically, the teacher explores a phenomenon with students to arrive at a canonical scientific explanation to account for the perceived discrepancy in the event (Nussbaum & Novick, 1982).

discrete experiences that operate as micro-level phenomena of short duration (Thoits, 1989). Unlike emotions, *feelings* are more generalized physical states (e.g., hunger, fatigue) that encompass emotional states, and *affects* are positive and negative appraisals of some experience (such as liking or disliking an idea). Drawing on the work of Thoits (1989), four common elements of emotion in sociological accounts include physiological changes, situational cues, expressive gestures and emotional labels. These elements interact with each other in a way that avoids reducing emotional experience to just one isolated component of it.

Within this conceptual framing, Turner (2007) theorized four primary emotions: assertion-anger, aversion-fear, disappointment-sadness, and satisfaction-happiness. These categories represent emotions that most researchers agree to be basic or primary (that is, components of human neuroanatomy). The first three emotion labels in the list represent negatively valenced emotions and the fourth is positively valenced. Primary emotions are experienced at different levels of intensity (e.g., irritated= low intensity aversion-anger; joy= high intensity satisfaction-happiness) or they can combine to produce first-order elaborations (e.g., pride= satisfaction-happiness + aversion-fear).

Emotional arousal. Two key factors are associated with emotional arousal: 1) sanctions, and 2) expectations states (Turner, 2007). Within Turner's 17 principles of the sociology of emotions, a number deal directly with the role that sanctions and expectations states have to play in the arousal of specific emotions and different valences and intensities. *Sanctions* are appraisals received by an individual as social feedback for their conduct. Principles in the theory focusing on sanctions follow the general formula whereby positive emotions are experienced when one receives a positive sanction and negative emotions result from negative sanctions. *Expectation states* refer to anticipatory feelings harbored towards a situation or encounter. The extent to which individuals experience positive or negative emotions is a function of expectations being met or unmet during interactions. For example, Turner's third principle asserts that when expectation states of self, other and situation for individuals are met during encounters, then individuals will experience positive emotions and negative emotions will ensue if expectations are not met.

Emotional Climate

Within groups, individuals' emotions become interactional resources for others involved in an encounter. This allows the sharing of emotions enabling an attunement towards the other which gives rise to a collective condition of emotional arousal. Emotional climate (EC) refers to the "sets of emotions or feelings that are shared by groups of individuals implicated in common social structures and processes" (Barbalet, 1995, p. 23) that are represented by a collective state of emotional arousal such as collective happiness (Tobin, Ritchie, Hudson, Oakley, & Mergard, 2013). Our conceptualization of EC is informed by the sociology of emotions (Turner, 2007) and interaction ritual theory (Collins, 2004). From these related theories, EC is produced during social encounters from which participants develop solidarity, or group belongingness, through rhythmic coordination of gesture and speech, mutual focus of attention, production of collective effervescence through group laughter and emotional attunement, and emotional energy. As a ritual outcome, collective effervescence is a state of heightened group experience whereby the group shares the same emotions (e.g., joy) and ideas. Through this process, shared ideas become symbols representing the group's interactions. The heightened emotional state experienced in forming these shared ideas flow on to the emotional energy experienced by individuals.

Emotional energy is the long-term outcome of the transient emotions experienced during an interaction ritual. It is the "confidence, courage to take action, [and] boldness in taking initiative" that an individual feels due to their experiences of successful interactions (Collins, 2004, p. 39). Participants who experience positive emotional energy during an encounter seek to reproduce like encounters and re-generate the positive emotional energy.

This results in rituals being repeated to form chains that can reproduce emotional energy and collective effervescence in the group and for individuals and thereby re-invoke the symbols (including ideas) of the original encounter.

We now outline three related elements in our theorization of EC. First, individual emotions and EC are interrelated dialectically so that EC is produced by and produces participants' feelings of emotional arousal during encounters. An individual | collective dialectic (Ritchie, Tobin, Roth, & Carambo, 2007) refers to the way in which individual actions, as well as positive or negative emotions, constitute the collective EC of a group (i.e., collective joy). The collective actions and EC also can contribute to feelings of similar emotional valences and intensities by individual participants. In this way, EC and emotions are constituents of a whole that may be represented as follows: *individual happiness | collective happiness*. In this example, the emotional label *happiness* describes both individual and group conditions of emotional arousal.

Our second elaboration relates to the spread of emotions between interaction participants, typically referred to as emotional contagion (Collins, 2004). Contagion is possible due to the mutual focus of attention on the same thing, and as individuals become aware of one another's focus, they get "caught up" in one another's emotions (Collins, 2004, p. 108). For example, as students become focused on a science demonstration, positive emotions spread quickly throughout the class to produce positive EC (Milne & Otieno, 2007). Emotional contagion serves to explain how the emotions experienced by individuals can lead to the development of a collective climate and emotional attunement.

Just as emotions can be characterized in terms of valence and intensity, so too can emotional climate. The third elaboration is concerned with valence and intensity of EC. Positive valence refers to EC associated with collective states of positive emotions (e.g., happiness and joy; Turner, 2007), whereas negative valence relates to negative emotions (e.g., sadness, fear, and/or anger; Tobin et al., 2013). EC also varies in intensity from highly positive EC to highly negative EC (Bellocchi, Ritchie, Tobin, Sandhu, & Sandhu, 2013). This is analogous to the way in which emotions vary in intensity; for example, *concern* is the low intensity emotion corresponding with the primary emotion of *fear* (Turner, 2007).

Science Demonstrations as Effective Practices that Arouse Emotion

The opening vignette introduced a potential relationship between a high quality learning experience focused on the professor's science demonstration and students' experiences of positive emotional arousal. A second type of demonstration, role-play, also emerged as a high quality learning experience in this study. In the sections that follow, we attend to previous research that has reported the benefits of science demonstrations called *predict-observe-explain* (POE), discrepant events and role-plays reinforcing their status as best practice in science education.

Discrepant Events and POE

Appleton's (1995) study focused on the use of discrepant event demonstrations taught through three different styles. He found that the effectiveness of the strategy is largely dependent on the specific form of instruction adopted by the teacher. When the teacher dominated the discrepant event discussions by proposing a canonical science answer to explain the observed phenomenon, this reduced opportunities for students to explore the phenomenon involved with the discrepant event. We show later in the analysis of episodes like the one in the vignette, that students and Donna exchanged turns at talk to construct a scientific explanation for the observed phenomenon during the explanation phase of the demonstration. In this way, the explanation was co-constructed through external dialogue rather than using a professor monologue and this allows different students to explore their own ideas as suggested by Appleton (1995). Dialogue, in this context, occurs when different speakers build on the utterances of preceding speakers (Wertsch & Toma, 1995). Dialogic practices in a professor's demonstration may afford preservice science teachers direct experiences about the use of dialogue, as opposed to monologue, for developing a canonical science explanation for the phenomenon in discrepant event demonstrations.

An important aspect of classroom emotions identified in the opening vignette is the expression of discrete positive emotions, such as surprise, wonder and happiness, associated with a high quality learning experience. Similarly, POE demonstrations have been shown to elicit positive emotions in high-school science classes (Milne & Otieno, 2007). A POE typically involves the presentation of a discrepant event by the teacher or student volunteers (White & Gunstone, 1992). Increased student engagement and positive emotions were generated in an urban chemistry classroom in the US when the teacher used POE demonstrations to illustrate the gas law concepts (Milne & Otieno, 2007). Milne and Otieno (2007) found collateral changes in student engagement and the expression of positive emotions with an increased willingness of students to move between different levels of representation in chemistry (i.e., macroscopic to symbolic) and more sophisticated use of the symbol systems of chemistry.

Role-Plays in Science

Another form of demonstration used in science teaching that is relevant to the pedagogy used by Donna is "role-play" (Dorion, 2009). In a multi-case study involving five science teachers in England, Dorion (2009) reported extensive use of role-play and other drama-style activities in their teaching practices. Teachers reported using these activities to "draw students' attention and focus, first to the topic itself, and second, to specific conceptual, affective or procedural features which the teachers wished to emphasize" (p. 2260). With respect to the affective nature of teachers' use of role-play and drama, the most common reason teachers gave was that they wished for students to experience enjoyment of learning in science. In this way, teachers offered emotive rationales for the inclusion of role-play in their practice.

Cognitive benefits of this teaching strategy have also been reported. One form of role-play used in science education, known as simulation role-play, involves students enacting the roles of different chemical compounds involved in scientific processes such as chemical equilibrium (Aubusson & Fogwill, 2006). Positive student learning outcomes in a high-school chemistry class were reported by Aubusson and Fogwill (2006) when the teacher, Fogwill, used role-play with his students to model chemical processes. Similar results to those in Dorion's study were reported by Aubusson and Fogwill (2006) who found that the use of role-play encouraged analogical thinking about science topics and resulted in deeper conceptual understanding as well as allowing students to offer different perspectives on science topics through social interaction.

Emotion Research in Science Education

Science education researchers are becoming increasingly interested in the role of emotions in learning to become science teachers and in teaching and learning in general. A growing number of studies are reporting the emotional experiences of preservice teachers and their professors in initial science-teacher education courses and the beginning years of teaching (Sinatra et al., 2014). The range of studies has included case studies of beginning teachers by Ritchie, Tobin, Hudson, Roth & Mergard, (2011), Ritchie et al. (2013), and Tobin et al. (2013), whereas other studies by Bellocchi et al. (2013) and Hong and Greene (2011) have focused on the experiences of University professors and students in preservice secondary education courses. From these studies, information is beginning to emerge about the centrality of emotions in becoming and being science teachers.

Emotions and Emotional Climate Research in Science Education

Some research in science classrooms has focused on assessing EC because it was related directly to a smooth flow of interactions between participants and high quality canonical science instruction (Tobin et al., 2013). EC became negative when members of a class tried to establish power relationships over one another. If the teacher or students tried to gain control of a situation by using a "cranky" voice, the EC decreased. In a different report of this teacher's classroom, positive EC was restored when the teacher recognized that interactions were falling flat (i.e., EC was becoming more negative) and she actively reproduced the kinds of interactions that had previously produced positive emotions and successful interactions (Ritchie, et al., 2011). By doing so, the teacher changed the structure of flat interactions into ones that reproduced positive emotions and restored a positive EC in the class.

In preservice science education, EC was related to students' learning experiences during debates about science issues (i.e., nuclear energy alternatives, global warming, GM foods) and to classroom interactions such as the dominant type of classroom talk (Bellocchi, et al., 2013). In that study, positive EC was associated with classroom interactions in which the students and professor were engaged in dialogue, whereas EC decreased during monologues by the professor or students. Interactions that involved dialogue tended to reflect the types of natural interactions that people experience during conversation between friendship groups. The study also indicated that relationships might exist between EC and discrete emotions but this was not explored in-depth at that time.

Past learning experiences (i.e., elementary and high school) of preservice teachers influence their perceptions of learning science and identities as science teachers more than their teacher education courses (Hong & Greene, 2011). Using questionnaires and semi-structured interviews with 11 preservice secondary science teachers, students' hopes and fears of becoming teachers were explored. Both cognitive (i.e., desire not to be boring) and affective (e.g., wanting to be caring) aspects of becoming teachers were related to preservice teachers' hopes and fears. The majority of reports of fear were associated with being ineffective and hope was associated with desires to be effective. Interestingly, personal past experiences such as church camps and tutoring were reported as influential on intended science teaching practices. Concerning the teacher education course, the participants focused on their school-based field experiences and interactions with teachers in schools and university classes as most influential to their intended future practices. These outcomes led Hong and Greene (2011) to suggest that preservice teachers require appropriate role models from whom they can "observe, learn and build a store of knowledge, skills, routine and attitudes required for a teaching career" (p. 508). The present study contributes to this growing body of work on science teacher education research by establishing a relationship between individual emotions and EC experienced in the moment with specific activities perceived as high quality experiences by the preservice science teachers. This aspect of secondary science teacher education remains under-researched.

Study Design and Preservice Science Education Context

The opening vignette illustrated an *event* perceived by students as a high quality learning experience that was associated with positive EC and positive emotions. *Events* describe happenings that have the power to modify *structures*–the outcomes and sources of human social practice (Giddens, 1979). Situated in an interpretive methodology, event-oriented inquiry informed the design of our study (Tobin & Ritchie, 2012). This methodology has roots in the work of Sewell (2005), who explored the changes to social structure in the context of historical events from a macro-sociological perspective. Event-oriented inquiry has also been adapted in science education to study micro-sociological classroom processes such as emotions and EC (Tobin & Ritchie, 2012). In this context, events are classroom happenings that can involve emotional outcomes for the participants such as changes in EC valence and intensity or changes in the expression of emotions. A key element of event-oriented inquiry is the commitment to adopting multiple data collection methods and techniques for data analysis. Within this approach, contradictions in the data as well as general patterns serve as resources for deepening our understandings of the central concerns of the study. In the context of classroom interactions two research questions informed the study:

1. What relationship, if any, exists between preservice science teachers' perceptions of high quality learning experiences, emotions and emotional climate?
2. How does the intensity (i.e., high, medium, low) and valence (i.e., positive or negative) of emotional climate relate to specific emotions and high quality learning experiences?

Preservice Teacher Education Context

The study took place in a preservice secondary science education class at an Australian University as part of a larger funded project focusing on the emotional experiences of university professors (i.e., Alberto, Steve and Donna) and their preservice students. We have reported previously one study of Alberto's class (Bellocchi et al., 2013) during the early stages of our project. We focus on Donna's class in the present study because the data from episodes such as the one in the vignette initially expanded our understanding of the interplay between emotional arousal and high quality learning experiences based on the earlier study.

Donna was an experienced science educator who had been teaching the methods subjects for four years before the period of the study. The class focused on introductory topics related to science teaching methods and curriculum studies for students in the second year of a four-year undergraduate secondary science-teacher education program. It was the first of three courses in the program that developed students' understandings of science classroom practices, curriculum design and assessment. Within the education program, students are prepared to teach two high school subjects (e.g., Science and English). There are designated courses that focus on curriculum, assessment and teaching methods related to each teaching area. In this way, preservice teachers gain knowledge about curriculum, assessment and instruction that is specific to their two high-school teaching subjects. Twenty-eight students,[2] out of fifty-five enrolled in the course, participated voluntarily in the study. Although this number of participants represented slightly over 50% of the class, not all research participants were present for every lesson. This was not uncommon as students tend to travel large distances from their homes to university and many opt not to attend face-to-face courses. As was typical in science education courses at the university, Donna tended to demonstrate how specific science concepts such as condensation could be taught through a range of different pedagogies including discrepant events, POE, and role-play as well as other topics such as lesson planning and learning about science curriculum.

Methods for Accessing Student Perceptions of Quality, EC and Emotions

Lessons were scheduled in two-hour blocks once per week during a 10-week semester. All lessons were recorded using three video cameras and a voice recorder worn by Donna. Consistent with the multi-method approach of event-oriented inquiry, three methods were used to capture students' experiences of the course: cogenerative dialogue (cogen), EC ratings, and video recordings of class interactions.

Cogen Data

Cogens provided data sources for understanding students' perceptions of high quality experiences and classroom interactions. Cogen is a dialogue about praxis between four or five students and the teacher (Roth & Tobin, 2005). An important feature of cogen is that all participants have equal voice, contributing ideas in order to reduce power relations between

[2] The University ethical board granted ethical clearance for the study. Participants signed ethics consent forms to participate in the study including release of their images. The professor was not aware of which students in the course were participants in the research until after the University issued final grades for the course.

students and teachers. Steve, the second author attended the first cogen and introduced the approach to students. He also monitored the balance of power between Donna and the participants in order to establish the desired interactional structures for subsequent cogens that she ran alone. Donna conducted five cogens in total and these were video recorded, transcribed, and reviewed by the research team. Four cogens took place during the teaching period whereas the fifth cogen took place after the semester had finished. The purpose of the fifth cogen was to gain feedback from students upon returning from their school-based teaching experiences. After cogen 1, an action plan was developed for improving learning and teaching in the course. Donna enacted the plan mostly in the following lesson. Students provided feedback about the implemented strategies in subsequent cogens.

Analyzing cogen data. Cogen transcripts were analyzed qualitatively to identify references made to the quality of preceding lessons. This post-hoc analysis involved searching for expressions such as "When [professor] did [action] this helps me in my teaching because…." We then analyzed video and audio recordings of the cogen interactions to determine whether other participants agreed with the statements. This involved identifying utterances like "I agree" or non-verbal cues like nodding. In this way, two types of class activities were identified as high quality learning experiences. Namely these were science demonstrations (POE and role-plays) and the professor's teaching reflections. High quality episodes were compared with EC data to establish connections between the learning experiences and class EC. We report selected events that represent the general themes in the data set. Examples drawn from different lessons illustrate general patterns as well as disconfirming evidence for any general claims.

Measuring EC

Participants rated class EC on a 5-point scale using audience response technology (i.e., "clickers")[3] as outlined by Tobin and Ritchie (2012) for all lessons throughout the semester. Students rated EC valance and intensity at three-minute intervals as 5= very positive, 4= positive, 3= neutral, 2= negative, and 1= very negative. One of the research assistants (i.e., SH) used an electronic buzzer to alert students at each time interval to input their ratings. In lecture one, Donna explained that highly positive EC is associated with intense positive emotion (e.g., intense happiness) and a highly uplifting collective mood, whereas highly negative EC is associated with intense negative emotion (e.g., intense sadness or depression) or a highly depressing mood (Tobin & Ritchie, 2012).

Analyzing EC data. As students inputted their EC ratings, the software calculated mean EC values for each time interval. Graphs of mean EC ratings vs. time intervals served as a heuristic for identifying salient events in the video data. Early in the semester, Donna presented the week one graph to the class and used it to reiterate how students were to rate EC. Intervals of time represented on the graph were aligned with video recordings of lessons to link participants' perceptions of EC with classroom interactions and their individual emotional experiences. This enabled us to analyze the full range of emotions experienced by participants that extended beyond the simplistic positive-negative binary for EC. An exemplary graph presented in the findings illustrates the broad patterns observed throughout the semester.

Micro-analysis of Video Data- Analysis of Emotion from Facial Expressions

Our analysis of EC data was complemented by microanalysis of video data to identify specific classroom interactions and the emotions experienced by individual students. This

---

[3] All students in the class were allocated clickers so that the professor could not tell the participants from non-participants during lectures. Only the clicker responses from research participants were included in the data set. During cogens, participants stated the use of clickers was not a distraction, as one student noted, "It woke me up."

involved the identification of the types of class interactions as well as different gestures, facial expressions, and vocalizations indicative of individual emotional arousal (Collins, 2004).

Analyzing emotional expressions. Individual students' emotions were identified from facial expressions. Three of us (i.e., AB, MS, SH) completed the Micro Expressions Training Tool (METT) and Subtle Expressions Training Tool (SETT) training (https://face.paulekman.com/face/default.aspx) to become proficient at analyzing facial expression of emotions[4]. These tools provide techniques for identifying emotional expressions derived from Ekman, Friesen and Hager's (1978/2002) Facial Action Coding System. This technique provided coverage of the primary emotions relevant to the study. For example, expressions such as the narrowing of the eyes are used to identify experiences of specific emotions such as mild anger. If the previous anger expression is also combined with a furrowed eyebrow, and baring of the teeth, this strengthens the case for identifying the emotion *anger* or intense anger (e.g., rage). Three of us (i.e., AB, MS, & SH) independently reviewed images from video data to identify emotions for each event reported in the study, and later compared our analyses to arrive at a consensus about the emotions.

Production of EC During Science Demonstrations and Professor Reflections

Two assertions are presented to support the claim that highly nuanced relationships exist between EC, emotions and the quality of learning experiences as perceived by preservice science teachers. These relationships involve the synergy between the types of classroom activities, interactional style (i.e., monologue/dialogue), and content of talk. The assertions are: 1) science demonstrations (POE and role-play) were high quality experiences associated with high positive EC and positive emotions; and 2) "teaching reflections" were perceived as high quality experiences even though the practice was associated with lower positive EC ratings and neutrality of emotion. Assertion 1 relates to research questions 1 and 2, and assertion 2 relates to research question 2. Relationships between emotions and different intensities of EC are discussed within the analysis of classroom events that pertain to each assertion. We begin with the first part of assertion 1 which relates science demonstrations to high quality learning experiences.

Science Demonstrations (POE and Role Play) as High Quality Learning Experiences

This section attends to the first part of assertion 1 that connects science demonstrations with high quality learning experiences. In three out of five cogens, students identified science demonstrations as high quality learning experiences. The three reasons students gave for valuing demonstrations during cogen included: 1) they linked together concepts from different science disciplines, 2) they provided practical ideas for science teaching, and 3) they were engaging. The following excerpt from the week four class illustrates the first reason for valuing demonstrations. It focuses on how Donna integrated science concepts related to a science demonstration about density to the context of organisms living in Antarctica in a post-demonstration discussion with the class:

> …if you think about it in the Antarctic, in really cold climates, you get the ice floating on the top because it is less dense than the water underneath and that enables all that aquatic life to live and survive and not freeze. (Donna, Week 4 POE demonstration)

Briefly, the demonstration involved a discrepant event related to density (i.e., the ice-cube POE). Two ice-cubes were individually placed in beakers with one beaker containing water and the second containing methanol. When the ice-cubes are separately added to each beaker, one floats in the water and the second sinks in the methanol. After the demonstration, the class constructed a molecular explanation by drawing on chemistry concepts for the

[4]Although through the METT and SETT training we developed the ability to identify microexpressions within 1/25th of a second, the accuracy of our analyses was increased by the ability to replay video recordings frame-by-frame.

observed phenomenon. In the excerpt from the post-demonstration discussion above, Donna was relating the chemical explanation for density from the ice-cube demonstration to concepts typically taught in high school biology by explaining how the floating ice permits aquatic life to survive in Antarctic waters. One cogen participant claimed that she "liked that it [Donna's demonstration] links with lots of different science concepts you could use [in your own classroom] and I like how you link it to the junior and the senior curriculum." This comment illustrated that students were attuned to the way in which demonstrations linked different concept from subjects like biology and chemistry and offered practical examples that preservice teachers could adopt in their own teaching. Another female student in the cogen compared the science teaching methods course, taught by Donna, with a different teaching-methods course such as English or Mathematics. The focus of instruction in the second course was on theories underpinning a new curriculum that was being introduced in schools across Australia. This student valued Donna's demonstrations more than the curriculum theory as captured in this cogen quote:

> we are just doing theory on this new curriculum [in the other methods course]…you're [i.e., Donna] actually giving me experiences I can use in my classroom and that's so much more useful because I'm gonna have that curriculum on hand anyway so these experiments are really good. (Student comment, Cogen 1)

The student's comment suggests that instruction focused on curriculum theory was redundant for her because she would have the curriculum document readily available as a teacher and could refer to this when necessary to inform her practice. In contrast, Donna's instruction in the science-education course modeled practical teaching strategies that are not readily available through curriculum documents. The practical nature of demonstrations meant that students found them useful and cognitively engaging learning experiences illustrating the third reason why students enjoyed the demonstrations. Two male students were also involved in the cogen. One of them commented that the demonstrations were "a nice way to get the class involved" and that they "woke up" the class. These comments reinforced the engaging nature of demonstrations by capturing their ability to gain the class' attention.

Three dimensions of high quality in teacher education are evident from events involving demonstrations. One dimension relates to professors modeling desirable classroom practices that are supported by research evidence (Kessinger, 2009). The second dimension relates to the efficacy of the demonstrations for generating engagement and learning with school science students; discrepant events, POE and role-play are well-established and effective classroom strategies with a strong evidentiary base in the science education literature (see Milne & Otieno, 2007). This reflects the research-based practice dimension of Kessinger's (2009) model of high quality teacher education. The third dimension of quality relates to long-standing arguments (see Shulman, 1986) in favor of teacher education that integrates learning science concepts with learning about teaching practices as illustrated through the excerpt about Antarctic life.

Science Demonstrations and Positive EC. The previous section provided evidence supporting part of assertion 1 which establishes connections between demonstrations and high quality learning experiences. We now attend to the second aspect of the assertion, that is, the connection between positive EC, positive emotions and demonstrations. Students reported in cogen that science demonstrations were associated with high quality learning experiences. The general pattern observed in this study (see Table 1) was that positive EC was associated with all of the demonstration lessons. Six lessons during the semester included POE/discrepant event demonstrations and two lessons also involved preservice teacher simulation role-plays in weeks one and four. Table 1 presents the EC ratings reported during the weeks of semester involving science demonstrations. Positive EC was produced during

POEs (EC range= 3.5-3.9) and during student role-plays (EC range= 3.6-4.0) that featured in weeks one and four. Students reported positive EC for all demonstrations but the EC intensity varied during different demonstrations with weeks six and eight having the lowest EC ratings (i.e., EC= 3.3 & 3.4) for the semester.

Table 1
Mean EC Ratings During Science Demonstrations Across the Semester

Week No.	Demonstration Name/Type	Mean EC Ratings
1	Rain in beaker demonstration + Role-play	3.8
2	Candies in Carbonated Drink demonstration	3.5
4	Sinking and floating demonstration + Role-play	3.9
5	Matches and detergent five-point start demonstration	3.9
6	Lava fizz demonstration	3.7
8	Balloon demonstration	3.7

Over the 10-week semester, the EC during POEs was consistently higher than during other class activities. For example, EC was low when the professor explained the science concepts related to the demonstration, which ranged from slightly negative EC (2.9) to positive EC (3.4), or during the presentation of lectures, which also ranged from slightly negative to slightly positive (EC range= 2.5-3.2). We begin our detailed microanalysis of selected events from lessons involving science demonstration that supported the general relationship of positive EC being associated with high quality learning experiences and science demonstrations as stated in assertion 1. Disconfirming evidence for this general pattern is also discussed.

Positive EC during POE demonstrations. During the semester, Donna typically combined discrepant event demonstrations with the POE teaching strategy. Our detailed analysis begins with one event involving the aforementioned ice-cube POE associated with a spike in the EC curve (EC= 3.9; see Interval 1, Figure 1) during week four. The horizontal axis on Figure 1 represents time intervals when students inputted their EC ratings. Time in minutes is also shown in parentheses for each data collection interval. The mean EC ratings are shown on the vertical axis. The numbers above each data point on the EC curve represent the number of participants who inputted their EC ratings for each time interval. The total number of respondents for the week four class was 17 and the number of respondents for each time-interval ranged from 6-17 for the duration of the class. Fluctuations like this in the number of respondents occur because of the short three-second time-frame in which participants can input their perceptions of class EC (i.e., some students don't input in time) and also because students may be focused on their activities and forget to input their ratings. These factors did not affect our analyses largely because we used the EC graphs heuristically to identify lesson segments relevant for video analysis.

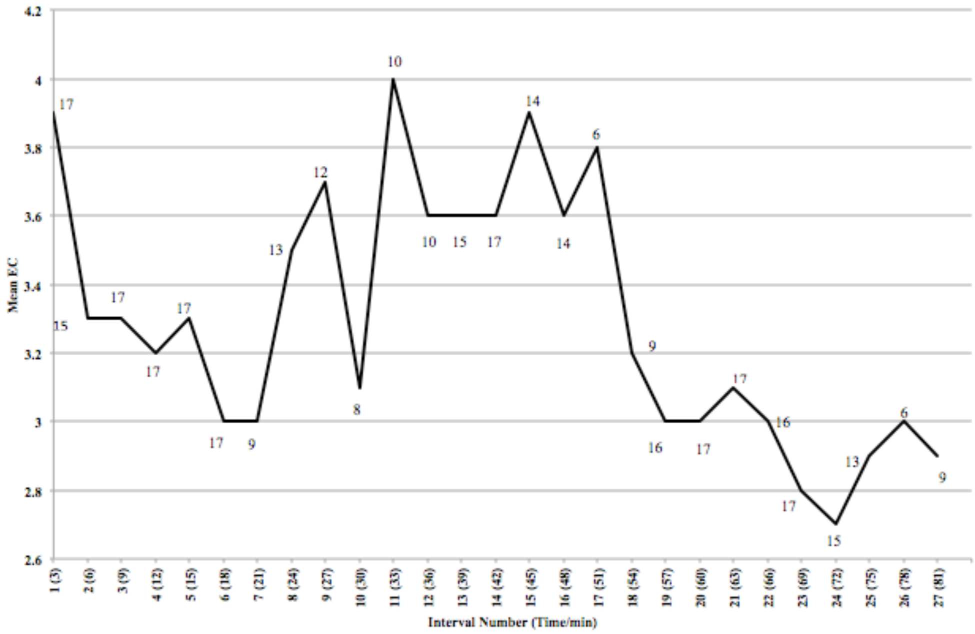

Figure 1 Class EC during Week four

The ice-cube POE began with Donna asking the class to predict what would happen when two ice-cubes were each placed into two different beakers containing clear liquids. Students were not yet aware that one beaker contained methanol and the second beaker contained water. Initially, the class was focused (i.e., attentive) on Donna as she showed the materials and explained that she was out to conduct a demonstration. During the prediction phase, the students turned away from Donna to face the group at their tables (up to 6 or 8 students per table) and discuss possible ideas for what would occur during the demonstration. Interactions became localized at the groups' desks and the room buzzed with conversation as the students made their predictions; the EC remained highly positive. Positive emotions were also noted during the observation phase of the POE. For example, in week five (used in the opening vignette) expressions of wonder and surprise were identified when students exclaimed, "wow" and "awesome" as the discrepant phenomenon unfolded.

Donna collected ideas from different groups around the class before proceeding with the "observation" phase in which she added ice-cubes to the beakers to test the class' predictions. The prediction and observation phases were resources that produced a positive EC structure (Interval 1, Figure 1). The low buzz of conversation that was present in the class during the prediction phase petered off as the students established mutual focus on the demonstration materials by re-aligning their bodies and heads towards the front bench and Donna. Time was then allocated for the groups at each table to discuss their observations and compare them with their predictions. The more localized nature of interactions at the group desks during this explanation phase changed the structure of the class interactions to one where exchanges were focused within small collectives. There were instances of collective laughter within the small groups as they discussed their observations but these were localized at specific tables and did not spread to the rest of the class. During this time, the EC remained positive but decreased (Interval 2, Figure 1) consistent with a lack of emotional contagion because the pockets of laughter did not spread to other groups in the class. High positive EC within the class is not likely to arise when students are focused on smaller group discussions at their tables. The reason for this is that the class cannot develop a sense of bodily co-presence of other groups, or individual students located elsewhere in the room, in the same way that they can when the whole class is focused on one symbol. This occurs because students tend to focus their attention on their group members and are not facing the other groups in the class.

High quality dialogic interactions. Although low positive EC ratings (EC= 3.3, Intervals 2-3, Figure 1) were registered during the explanation phase, we interpret the interactions as constituting high quality experiences because students participated in dialogue to develop collaboratively explanations for observed phenomena. Dialogue is a desirable form of classroom talk because participants co-construct their understanding of ideas rather than receiving information through teacher monologue (Scott, Mortimer & Aguiar, 2006). For example, in the post-demonstration discussion, Donna invited students to develop a scientific explanation for the observed phenomenon. One student began the explanation by introducing the concept of density to explain why the cubes either sank or floated. Other students built on this student's response by elaborating that density refers to, "How closely packed the molecules are." This new utterance built on the utterance from the initial speaker, developing a dialogue, by adding a particle theory explanation to elaborate the concept of density introduced by the first speaker. This dialogic interaction continued (see Turn 15 Extract 1) during subsequent turns at talk as the first speaker then elaborated further the close packing of molecules by providing details of the bonding of atoms.

Extract 1 Dialogue During Post-Demonstration Discussion of Ice-Cube POE

Turn #	Speaker	Transcript[5]
15	Student 1	The way that ice forms together when it bonds, the hydrogen and oxygen are actually further apart, all the the molecules of hydrogen and oxygen further apart than when it's a liquid form, cause they bond.
18	Donna:	… Okay, so if I do this ((draws structural formula diagram of water molecule)) … do you want to just explain that to the group. you're ((i.e., student 1)) doing really well
19	Student 1:	Well if you can put another oxygen and hydrogen directly to the right, yeah ((Donna continues writing on the board)). See the oxygen and oxygen are closer together in that instance but in a solid f-, in its solid form the hydrogen's are closer together and the oxygen's further apart because they're branched
20	Donna:	In the solid form [the hydrogen's [are closer together=
21	Student 1:	[it's=
22	Student 2:	=draw hydrogen now
23	Student 1:	=see they sort of like becomes a Greek [key] pattern, so you have an oxygen on the end of your hydrogen yeh that's it ((refers to Donna's diagram based on student 1's explanation)).
24	Donna:	Ok so you are saying that it's something to do with the way they align themselves ((gesturing with hands to illustrate orientation of water molecules)) based on the structure of the water molecule and Student 1's onto something really important here about the water molecule. ((student 3 raises hand)) Student 3?
25	Student 3:	is that because it's due to the polarity of the oxygens and the hydrogens?

Donna invited Student 1 to draw a diagram to aide in his explanation, to which he declined so she facilitated the student by drawing diagrams herself (Turn 18) on the student's

[5] The relevant transcript conventions (Roth & Hsu, 2010) used in extracts include length of pauses, shown by placing the time in parentheses (0.2), latching turns of talk indicated by the equals sign (=), and researcher comments in double parentheses ((raises hand)).

behalf. Student 1 then made reference to the lattice structure of water molecules when they form a solid in Turn 19. Donna presses the class further by asking them to elaborate on the properties of water molecules in Turn 24 by referring to Student 1's utterance. Student 3 builds on the explanation by referring to the polarity of the bonds between hydrogen and oxygen in water molecules that are significant in determining the bent shape of water molecules that allows them to form lattice structures when water becomes a solid. In this way, conceptual understanding of the explanation was socially constructed through dialogue amongst the three students as Donna facilitated the discussion through various prompts. Each speaker used concepts and words introduced by other speakers as they constructed their explanation.

A valuable aspect of the science demonstrations used by Donna is that as well as learning professional knowledge and science concepts in an integrated way, the knowledge was contextualized through Donna's demonstrations and modeling of classroom dialogue and it took place within an emotional matrix dominated by positive EC. As Shulman (1986) suggested instruction that is "stripped" of context and emotional experience is undesirable as students may not remember it or use it wisely as future teachers. Variants of the emotion happiness (i.e., gaiety, joy) and positive EC shrouded class interactions during Donna's demonstrations. Participants reported during cogen that these experiences were valuable and highly engaging thereby providing empirical evidence supporting Shulman's claims about the value of contextualized and emotional learning experiences on preservice teachers. Two male students attended cogen five which took place after the class had attended a high-school based field experience. One student indicated that he had asked the science assistant at the school for materials to conduct a discrepant event chemical demonstration but was declined the opportunity due the equipment being unavailable. Although he did not get to practice what he was taught by Donna, his initiative to put into practice the discrepant event was evident. In the end, he used a video of the chemical reaction to demonstrate it to the class. This provides some evidence that students do carry out their intentions to enact the teaching practices that they had learnt.

Science Demonstrations and Low EC. Contradictions to the generally positive EC ratings during POEs occurred during weeks one and two. The EC ratings in those weeks were closer to neutral (i.e., EC= 3.0) during the course of the demonstration. This was lower than the positive ratings observed consistently in weeks three to ten (EC range= 3.7-3.9). It is possible that the low EC in week one occurred because the demonstration did not produce an instantaneously observable result and the class did not return to making their observations for 25 minutes. During the lesson, students commented that the demonstration could have been set up before they had arrived to class so that the intended phenomenon could have been observed in a shorter timeframe. In week two, a chemical reaction critical for the demonstration did not occur in the way that was expected so there was no pay-off for the students' attentiveness. The demonstration typically involves a rapid chemical reaction between a carbonated drink and sugarcoated candies. By inserting the candies into the bottle of carbonated drink, a pressurized fountain of drink forms due to a chemical reaction between the sugar coating on the candy and the carbonic acid in the drink. However, in Donna's demonstration the fountain effect did not ensue once she added the candies. Student familiarity with this very common demonstration, popularized on television programs and social media, could have raised their expectation states for a spectacular outcome. When the reaction did not take place, the demonstration failed to meet their expectations. As Turner's third principle states, when expectations for an encounter are not met, negative emotions are aroused.

Positive EC and Role-Play. Lessons in weeks one and four featured role-play demonstrations. The science concept relevant to the week four role-plays was the condensation of water. After the ice-cube demonstration by Donna and the discussion of how she would teach condensation in the context of the water cycle to an 8th grade science class, the preservice teachers were given one minute to develop a role-play about condensation. One student group was called upon to present their role-play to the class. Collective laughter was observed throughout the class, including the presenting group, during the role-play. This was triggered by two group members (S1 & S2) who had hunched down and swayed their torsos while waving their outstretched arms to represent the movement of water molecules in the liquid state. Donna, who was standing away from the group, then requested that the other two group members (S3 & S4) also participate in the role-play (Turn 2, Extract 2) because they had not become involved.

Extract 2 Co-construction of Condensation Role-Play Between Donna and Students

Turn #	Speaker	Transcript
2	Donna	Come on. ((to S3 & 4)) All of you, all of you! ((class laughs, role-play group are smiling))
3	S3	We said it clumps together ((moves from the side to the center of her group. Gestures with hands in embracing motion to illustrate "clumping")) Like it was water vapor and then they ((the molecules)) all clump together ((the role-play group move closer together))
4	Donna	Very good. All right. And they actually move a little bit around ((students S3 and S4 begin to move)) each other ((Donna steps towards group, whole group starts to weave around one another)) Yeh, they can move yep ((loud laughter in the class)) but they clump together.

One of the side dwellers, S3, stepped to the center of the group to explain how water molecules in the gaseous state eventually "clump together" to form the liquid state (Turn 3, Extract 2). She gestured with her hands in a prayer-like position to represent the clumping of water molecules. By joining her hands and inter-lacing her fingers, the student represented the molecules becoming more strongly attracted as they formed the liquid state. The student's use of the word "clump" shows synchrony with Donna's explanation of condensation earlier in the lesson during which she used "clumping" to explain the attraction between water molecules during condensation. The group members huddled closer together than in previous stages of their role-play to illustrate the closeness of water molecules in the liquid state relative to the gaseous state, consistent with S3's explanation in Turn 3. Donna then extended S3's contribution by stating that the water molecules "move a little bit around each other" (Turn 4), which the group members began to enact by weaving their bodies around one another.

In Turn 4, as Donna uttered "around" to indicate that the molecules move, S3 began to move her shoulder as the "a" in "around" was spoken. This movement, which was synchronized with Donna's utterance, was the beginning of the student using her body gestures to represent the motion of water molecules suggested by the professor. As S3 did this, the other group members also began their movements within 0.6 seconds, in time with Donna completing the word "around." The synchrony between student actions and Donna's utterances demonstrate a level of entrainment in the group and suggest that solidarity was developing between these students and Donna. The short time interval between each action and speech of the participants is another indication of the successful nature of these interactions. In this way, the condensation role-play became a co-construction between the student group and Donna in which the concept of condensation was represented through dialogue, hand gestures, and bodily movements that represented high levels of interpersonal attunement due to the short time frames between gestures.

Our analyses indicate that role-play could become a symbol for this class that is saturated with the positive emotions felt during moments like the one represented in Extract 2 for the student group and the whole class. According to interaction ritual theory, group members focus their emotions on an object that can take the form of specific words, artifacts, or materials. The combination of talk, gestures and the activity of role-play-for-teaching-science, collectively are the "object" of focus for the class that became imbued with positive emotional energy produced at the moment of its enactment. The positive emotional experience shared by the class during role-plays could encourage them to want to reproduce the strategy in their own school science classes according to interaction ritual theory.

Specific emotions and EC during role-play. As well as participant reports of positive EC during the role-play demonstrations, the condensation group members expressed the emotion of happiness as seen from their upturned lips, slightly raised cheeks, and slightly opened mouths (Ekman, 2007). More specifically, this facial expression represents medium intensity happiness (i.e., cheer, enjoyment; Turner, 2007) because the corners of the mouth and cheeks were not uplifted to the full extent possible. Similar patterns of smiling and laughter were also observed in five out of the six lessons involving science demonstrations, which coincided with high EC ratings.

Consistent with the happy facial expression of the presenters, quiet laughter began to bubble up in the class while Donna uttered "Yeh" in Turn 4 of Extract 1 and the student group began to enact her suggestions that the water molecules should move around. As she finished uttering the word "yep" at the end of Turn 4, loud laughter spread contagiously throughout the class. This laughter was louder than the quiet laughter that preceded it. Within 0.3 seconds of the loud outburst, Donna began to smile (corners of her mouth rose, cheeks rose) and she joined the collective laughter of the class. Her facial expression was also consistent with cheer and enjoyment. The role-play group once again expressed happiness but this time it was more intense (i.e., gaiety, joy; Turner, 2007) than the earlier interactions as their cheeks were raised higher and their eyes were slightly squinting which are signs of more intense happiness (Ekman, 2007). All but one group member sustained smiles for 10 seconds. This prolonged expression of happiness indicates that it was an intense emotion because most emotions last only a few seconds (Ekman, 2007). The increased intensity may have resulted from Donna's own laughter and smile at the students' actions. We interpret the effects of Donna's laughter on the class in two ways. One way is that her laughter acted as a positive sanction for the students' actions that in turn fuelled their laughter and expression of positive emotions (e.g., Turner 2007). The second way we interpret the laughter is that it shows that Donna was complicit in the students' frivolity. As Roth, Ritchie, Hudson and Mergard (2011) suggest, when the teacher and students are complicit in frivolity, this builds interpersonal relations in the class and leads to further expression of positive emotions consistent with the more intense smiles expressed by the role-play group. The expression of happiness by the group and the laughter of the class contributed to the highly positive EC (EC= 4.0) during the role-play demonstration. This analysis of the role-play activity supports our conceptualization of the individual | collective dialectic relationship between positive EC and individual emotions because different students expressed happiness at different intensities and at the same time the class rated the EC as highly positive. The EC was higher during the condensation role-play (EC= 4.0) in week one when compared to earlier interactions in that lesson during which Donna explained condensation through a monologue. During the monologue, the EC was close to neutral (EC= 3.1) and there was no laughter or expression of positive emotions evident in the class based on facial expressions. This result extends findings from previous research (Bellocchi, et al., 2013) that found professor or student monologues were typically associated with decreases in EC or lower levels of positive EC during classroom activities focused on science debates.

Reproducing role-play reproduces positive EC. As reported in Table 1, a second round of role-plays occurred during week four (Intervals 11-17, Figure 1) in which the class formed seven groups and each group took its' turn at presenting a role-play to the remainder of the class. In week four, student groups were allocated more time to plan their role-plays collaboratively before presenting them to the class.

At Intervals 11, 15, and 17, similar structures to the condensation role-play were reproduced that involved positive spikes in the EC curve and laughter in the class. For example, a student from the first group of presenters (i.e., Interval 11) announced in a loud voice "Welcome to the ion swinger couples show" resulting in loud laughter and facial expressions of happiness in the class. Their role-play represented the double-displacement reactions that can occur between solutions of ionic compounds in water. That is, during double displacement reactions, the ionic species that form one compound "swap" with those of another compound resulting in one new compound forming a precipitate and a second new compound remaining in solution. In the role-play, one student-couple swapping partner with another student-couple at a swinger's party represented this.

Not all of the student role-plays presented during week four reached the same levels of positive EC intensity as the ion-swingers role-play. These slightly lower intensity events (i.e., Intervals 12-14, & 16, Figure 1; EC= 3.6) provided contradictions in our data set to the higher levels reached at Intervals 11, 15, and 17 (EC= 4, 3.9, & 3.8 respectively). Video analysis of the lower intensity events showed that although the audience was attentive—a low intensity positive emotion (Watson & Clark, 1994)—stronger emotions like gaiety and joy were not produced for prolonged periods like they were during the condensation or swinger couples role-plays.

Notwithstanding the difference in intensity between the different role-plays during week four, it was clear that role-plays generally produced positive EC (EC range= 3.6-4.0). Furthermore, higher intensity positive emotions were associated with role-plays; whereas other class activities such as professor monologues produced EC intensity close to neutral (e.g., Interval 10; EC= 3.1). An aspect of quality that was raised by students during cogen related to class engagement. Students explained "engagement" as active involvement in class such as answering questions, participating in discussions, and paying attention by facing the professor. Engagement is an important aspect of the degree of quality in higher education because it contributes to university students' willingness to persevere with a course of study (Kuh, 2003). Donna's activities were academically engaging because the students learnt experientially the knowledge about teaching practices associated with using role-play for science instruction. The positive emotions and EC in the class were key features of interactions during these experiences that charged class interactions leading to heightened collective effervescence and fuelling class engagement.

"Teaching reflections" are High Quality Experiences Associated with Low EC

This section deals with assertion two which presents a connection between high quality learning experiences, teacher reflections and low EC ratings. Such a relationship is important because it contradicts the general pattern between high quality and high positive EC established in Assertion 1.

Types of teaching reflections. There were two different types of teaching reflections that Donna engaged in during her lessons. One type occurred when she presented the science demonstrations as captured in the following utterance used to introduce the week four ice cube demonstration: "Try and build a little tension with the kids, what's going to happen? Let's see what's going to happen." In this case, Donna was suggesting how to manage the presentation of the activity to build up a mood of suspense that is associated with discrepant events. Her question "what's going to happen" is uttered with a decreased tone to suggest expectancy, therefore the tone of her voice as well as the content of the utterance modeled how the activity could be presented to engage science students. This helped to build an image of an 8th grade classroom context in which demonstration might be used, and modeled the use of vocal expression that might build a desirable mood of suspense for the demonstration.

Other cases of the first type of teaching reflections occurred during the post-demonstration discussions. The following example occurred after a POE during week two (see also Table 1, Candies in Carbonated Drink):

> So when you're doing this [i.e., the discrepant event and POE] with a class of children you'll see that I set up the discrepant event you watched…you did the POE…I do realize though that *I rushed through the explanation and that may be too fast for an 8th grade class*. (Donna, Week 2; emphasis added)

Donna was externalizing to the preservice teachers how she may have conducted the activity differently with an 8th grade class when she stated that the pace of her explanation was too fast. Similarly, in week six Donna provided a spontaneous reflection related to a concept mapping activity about atomic structure. As a group of preservice teachers completed a concept map on the whiteboard, Donna made the following reflection: "So you need to know your basic structure of your atom to be able to do this, you see how kids in grade 9 and 10, how this would really test their understanding of atomic structure?" The reflection was focused on the challenge that the activity had presented for the preservice teachers and Donna used this to reflect with the class on the way the same activity would challenge high school students in her comment. Such reflections provided students with insights into the way in which an experienced teacher would plan to use the demonstration by explaining that the pace of her instruction was not suitable for 8th grade students. As one student explained in cogen one, this is valuable for preservice teachers: "When you [Donna] explain what you do and why you do it [it] impact[s] on [us] as future teachers because it gives [us] a chan[ce] ahh maybe I can do that in a similar case." In this way, reflections can be empowering for students because they allowed them to imagine how they might adopt the pedagogies in their own teaching.

The second type of teaching reflection occurred when Donna evaluated her own classroom teaching. An example of this occurred in the ice-cube POE lesson. Donna had been asked by cogen students to give examples of *questioning techniques*. Questioning techniques were important to the class because they featured in the assessment of the unit that involved student microteaching presentations. During the ice-cube lesson following the cogen, Donna modeled two questioning techniques. One technique was *wait time* (i.e., allowing longer pauses when a teacher asks challenging questions) and the second technique involved questions targeting higher order thinking. After the demonstration, Donna asked students to devise an explanation for their observations. She then paused and counted to demonstrate the wait time technique as follows: "All right, so here's my higher order question why did that [referring to the phenomenon in the demonstration] happen? One Mississippi, two Mississippi, three Mississippi." The three-second pause generated by the wait time technique (i.e., "One Mississippi, two Mississippi, three Mississippi") is used when asking a challenging–or higher order thinking–question ("Why did that happen?"). None of the students raised their hands to respond to the question despite the long pause. Donna then reflected on her practice in the moment by stating "…if you only get a couple of students in the class with their hands up what should that make you think as a teacher perhaps?" A student responded by suggesting that Donna's original question may have been too challenging. In this example, Donna externalized her thoughts about what to do as a teacher when the wait time technique did not produce the desired result (i.e., few or no students raised their hands to respond).

Low EC, emotions and high quality learning experiences. Low EC ratings were recorded during teaching reflections. Although the teaching reflections coinciding with low EC ratings, students reported during cogen one that they valued these reflections as follows: "Even self-reflection after you've done your little discrepant event at the start … by showing us the *tools* that you are bringing into your presentation we can see what the tools are and steal them for ourselves." Two of the other three cogen participants nodded in agreement when the student made this point. The student's remark is important to our understanding of high quality learning experiences because it suggests that Donna's teaching reflections are empowering for him as they can inform his future practice as a science teacher. Identifying experiences that are considered empowering for students is an indicator of high quality in tertiary education (Harvey & Green, 1993). The student referred to Donna's advice as "tools" that can inform his own practice. He did not mean the materials for the demonstration in the literal sense; rather he was referring to the kinds of questions Donna was asking during her presentations and the practical advice she shared for conducting the activities within high school science classes (e.g., the example discussion about Antarctic life).

The EC rating during the wait-time discussion was close to neutral (EC= 3.1), which is low when compared to the previous positive rating (EC= 3.9) during the ice-cube demonstration. Before modeling the wait-time questioning practice, Donna had explained techniques for higher order thinking questions through a long monologue during which the EC reached a negative value (EC= 2.5). Despite the EC becoming negative, the explanation and modeling of the technique had positive effects on the students during their microteaching presentations. In cogen 4, one student noted these positive effects during her peers' presentations as follows: "Just by looking at the [micro-teaching presentations] you can say that people after understanding [the questioning technique] you can see that people are getting that higher order thing going in their [micro teaching]". This student attributed the improved quality of questions asked by her peers to Donna's instruction on questioning techniques. To a lesser extent we had evidence from cogen 5, which took place after students attended their school-based field experience, of one preservice teacher successfully implementing the higher order thinking question technique (based on Bloom's Taxonomy) with a 10th grade science class. He described that the technique challenged the students to think more deeply about their work as follows:

> And that was the whole idea of using…the Bloom's taxonomy [questioning technique] where we're saying make something out of what you know [i.e., applying knowledge] rather just rote recall, practice questions because they had to do some practice questions they had to actually think it through.

For the preservice teacher this was a successful implementation of what Donna had modeled in her own teaching. Only two students attended the fifth cogen so evidence of this kind of impact on their teaching practice was limited in the data set.

Despite the EC reaching a negative value during reflections and professor monologue, the benefits to the class were evident as the students adopted the questioning techniques taught and modeled by Donna during microteaching. Microanalysis of video data during teaching reflections showed that students alternated their body and head orientations from facing Donna to facing their desks or notebooks. Intense facial expressions of positive or negative emotions were not identifiable. Students' facial expressions were neutral and their body and head postures were facing Donna indicating that they were attentive. This finding allows us to establish a relationship between low EC ratings (EC range= 3.0-3.6) at times with neutrality and at other times with the discrete emotion of attentiveness (a low intensity positive emotion; Fredricks, Blumenfeld, & Paris, 2009).

The class activities related to teaching reflections discussed in the preceding sections inform our understanding of the relationship between valence and intensity of EC and student perceptions of high quality experiences by illustrating that lower positive EC and slightly negative EC on one occasion is related to high quality experiences. We can summarize our findings by stating that high intensity positive EC is associated with high quality experiences that engage students and involve dialogic interactions as seen in Assertion 1. However, low intensity positive EC is also an indicator of high quality instruction when it is associated with teaching reflections that provide students with teaching "tools" and that build students' knowledge about teaching practices as reported in this section relates to Assertion 2. Collectively, assertions 1 and 2 support the argument that the synergy between emotions, EC and high quality experiences is a complex and highly nuanced process.

Emotional Climate and Quality in Science Education

We contribute understandings about preservice teachers' perceptions of high quality learning experiences in science education by identifying the role of individuals' emotions and classroom EC. Highly engaging and emotionally positive responses to science demonstrations are associated with high quality, but lower positive emotional experiences—and on one occasion, negative EC—associated with teaching reflections and professor monologues are also considered high quality. Teaching reflections were high quality experiences because they divulged "insider information" about the decision–making process adopted by experienced teachers. Preservice teachers found this beneficial for their future teaching experiences. The underlying pattern related to these perspectives is that teaching and learning episodes continue to be perceived as high quality if they are likely to add practical value to preservice teachers' repertoires. The valence and intensity of EC and emotions is related to the nature of the activity. Science demonstrations are highly engaging and associated with positive EC and the emotions happy, surprised, wonder, gaiety and joy. Teaching reflections are associated with attentiveness, neutrality and low EC in general. Our study has identified a more complex interplay between emotions, EC and the quality of learning experiences than simple formulas that might equate positive emotion and EC with high quality learning experiences. The findings point to conceptual and empirical advancements in understanding the interplay of the quality of learning experiences with emotions and EC during classroom interactions.

Turner's (2007) sociological theory of emotions provides a series of principles that could help to understand why the relationship between perceptions of quality and EC or emotions cannot be explained by the rhythm of the interaction alone. Turner's (2007) third principle states that when the expectation of self, other and situation for individuals are met during encounters, then positive emotions will be produced; negative emotions result from expectations not being met. This relationship depends in part on the extent to which the encounters are embedded in an institutional domain. In our study, science demonstrations and teaching reflections are situated within the domains of science education and science teaching. Preservice teachers are aware of this and understand and value the activities because their expectations of learning skills and knowledge relevant to these domains are being met by the professor. This leads to the production of positive emotions, albeit of differing intensities—high during demonstrations, low during reflections. The findings suggest that successful interactions that require high intensity emotions, as predicted by interaction ritual theory (Collins, 2004), are not the only salient aspect of high quality experiences. An additional aspect is the meeting of expectations in ways that leave preservice teachers feeling empowered towards the profession. Feelings of empowerment in this study were related to the relevant content, to the modeling of classroom practice, and the reflections on this practice.

Expanding Prior EC and Emotions Research in Science Education

Recent studies have explored EC in high school settings (e.g., Ritchie et al., 2013), middle school settings (Tobin et al., 2013), and preservice science education settings (Bellocchi, et al., 2013) by using methods and theoretical orientations consistent with those used in the present study. We extend this previous research by establishing connections between students' perceptions of EC and high quality experiences through cogen, and the relationship between individual's emotions and the collective class EC. Previous research has not investigated these interactions extensively.

Interactions during science demonstrations and teaching reflections were nuanced with elements of classroom dialogue and professor monologue being intertwined during different parts of the activities. Dialogue was evident during post-demonstration discussions focused on building class explanations for discrepant phenomena. The professor used monologue during self-reflection on her teaching and to address topics valued by students in cogen such as questioning techniques. Data from the present study support the claim that long monologues are associated with decreases in EC or negative EC as identified previously by Bellocchi, et al. (2013). Yet, the present findings suggest that sometimes this is associated with valuable learning experiences if preservice teachers feel empowered by the content of the monologue. The different structures of the predict, observe, and explain phases of the POEs, student presentations during role-plays, and teacher reflections provided resources for different types of interactions. These interactions included monologues and dialogue that in turn produced different intensities of positive emotions and EC. Through these interactions, the professor shared stores of knowledge, skills, and dispositions that are likely to affect preservice teachers' future practices (Hong & Greene, 2011).

We observed how Donna and her students socially constructed canonical science explanations for observable phenomena and their understanding of teaching strategies associated with science demonstrations. The social construction of knowledge took place within a broad matrix of emotionality. This finding is reinforced by Alsop's (2011) claim that the separation of emotions and mind or cognition is simplistic. Although Alsop (2011) was referring to the dualism between emotions and learning science concepts, in our study we have shown that learning to teach science consists of both cognitive and emotional processes that render dualistic interpretations of emotion and cognition to be redundant. In Donna's class, the outward expression of emotion was a legitimate practice (Alsop, 2011) associated with learning to be a science teacher. It became legitimate through Donna's sanctioning of laughter during science demonstrations and through her own participation in the laughter. Her dispositions towards science teaching may also inform preservice teachers' future practices (Hong & Greene, 2011). An interesting follow-up study would be to track her students into their early years of teaching to see whether they reproduce similar emotional encounters with their science students, in much the same way that Ritchie did (Ritchie et al., 2011; 2013).

Research has shown that emotional changes occur when high school science teachers use science demonstrations (e.g., Milne & Otieno, 2007). Our study also contributes new understandings about the relationship between specific emotions (e.g., gaiety, joy, happiness, surprise, wonder) expressed by individual students and the associated high positive and low positive EC during class activities. Emotional changes took place during learning about the different teaching strategies and during different stages within the same teaching strategy such as the phases of the POE. In this way, we understand that demonstrations do not arouse positive emotions and EC throughout their duration. For example, *wonder* and *surprise* were observed during the observation phases of a POE, whereas the lower intensity positive emotion *attentiveness* was observed during the explanation phase. These subtle shifts in positive valence did not affect the students' appraisal of POE as a high quality learning experience indicating that short moments of high intensity positive emotion may be adequate for learning experiences to be perceived engaging.

Emotional change–that is, swings in EC and changes in emotions associated with learning episodes–is a conceptual tool that may afford researchers a different perspective on learning from the dominant conceptual perspective that has so far informed our understandings. The emotional changes observed in our study included high positive EC and gaiety/joy/happiness/surprise/wonder when the class was engaged during the presentation of role-plays and aspects of the POE, to low positive EC and attentiveness during the pre- and post-demonstration discussions and during teaching reflections. Collectively these emotional fluctuations constitute the high quality learning experiences reported in this study.

Our results extend the initial conceptualization of EC presented at the beginning of the study by identifying specific emotions associated with different positive EC ranges. In the EC range= 3.0-3.6 the class was attentive and focused—low intensity variants of happiness. Attentiveness, a positive emotional state of low intensity (Fredricks, Blumenfeld, & Paris, 2009), and focus are signs of emotional engagement. The EC range= 3.6-4.0 is comprised of high intensity positive emotions such as gaiety, surprise, wonder, and joy. The extent to which negative emotions are expressed during the time intervals used to rate EC is not evident in our data despite EC becoming negative at times. Within an interval individuals may experience both positive and negative emotions. The positive emotions could saturate an event in such a way that EC does not reflect negative emotions to any great extent. Future studies should focus on negative emotions by combining self-report instruments like emotion diaries with the methods in the present study to understand better what role negative emotions have to play in classroom life.

Implications for Quality Indicators in Preservice Science Teacher Education

Models of preservice teacher education have been proposed that integrate experience, theory and wisdom (Lunenberg & Korthagen, 2009). One suggestion related to developing wisdom is for professors to engage in dialogue with preservice teachers about their prior experiences as high school students. Feelings about past experiences can help preservice teachers to become more sensitive about what is happening in their own work as teachers. One limitation to this approach is that the wisdom derived from past experiences may involve 'tricks that work' as opposed to practices that are informed by educational theory (Lunenberg & Korthagen, 2009). In our example of Donna's teaching reflections we see a different possibility for the development of practical wisdom. If the professor externalizes aspects of his/her own practice in the moment this has the advantage of allowing preservice teachers to see how a teacher draws on theory and experience in his/her practice. One way of extending Donna's reflective practice would be to ask students what educational theories and practices studied in their science education program they can associate with teacher reflections. Another extension would be for professors to explicate any practical theories they perceive as salient to their reflection.

We encourage teacher educators to use teaching reflections within a broader repertoire of teaching practices and classroom experiences such as modeling science activities and science demonstrations. Because teaching reflections are associated with low EC, it is essential that other experiences, which produce higher positive EC, are included to maintain student interest and engagement over time. Professors could use our findings to sequence learning activities in such a way that there are high EC activities planned at the beginning, middle and end of a lesson and semester in order to maintain an overall positive EC and to maintain engagement throughout the entire period of instruction. Practitioners could use similar strategies as those reported in our study to enhance the emotional experiences of their classes.

References

Alsop, S. (2011). The body bites back! Cultural Studies of Science Education, 6, 611-623.

Appleton, K. (1995). Problem solving in science lessons: How students explore the problem space. Research in Science Education, 25, 383-393.

Aubusson, P. J., & Fogwill, S. (2006). Role-play as analogical modeling in science. In P. J. Aubusson, A. G. Harrison, & S. M. Ritchie (Eds.), Metaphor and analogy in science education (pp. 93–104). Dordrecht, The Netherlands: Springer.

Barbalet, J. M. (1995). Climates of fear and socio-political change. Journal for the Theory of Social Behavior, 25, 15-33.

Bellocchi, A., Ritchie, S. M., Tobin, K., Sandhu, M., Sandhu, S. (2013). Exploring emotional climate in pre-service science teacher education. Cultural Studies of Science Education, 8, 529-552.

Collins, R. (2004). Interaction ritual chains. Princeton, NJ: Princeton University Press.

Dorion, K. R. (2009). Science through Drama: A multiple case exploration of the characteristics of drama activities used in secondary science lessons. International Journal of Science Education, 31, 2247-2270.

Ekman, P. (2007). Emotions revealed. New York: St Martin's Griffin.

Ekman, P., Friesen, W. V., Hager, J. P. (1978/2002). Facial action coding system: The manual [CD-ROM]. Salt Lake City, Utah, U.S.A.: Research Nexus.

Feldman, A. (1997). Varieties of wisdom in the practice of teachers. Teaching and Teacher Education, 13, 575-773.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2009). School engagement: Potential of the concept, state of the evidence. Review of Educational Research, 74, 59-109.

Giddens, A. (1979). *Central problems in social theory: Action, structure and contradiction in social analysis*. Berkley, CA: University of California Press.

Goodwin, A. L. (2008). Defining teacher quality. In M. Cochran-Smith, S. Feiman-Nemser, J. D. M[c]Intyre, K. Demers (Eds.), Handbook of research on teacher education (pp. 399-403). New York: Routledge.

Harvey, L., & Green, D. (1993). Defining quality. Assessment and Evaluation in Higher Education, 18, 9-34.

Hong, J., & Greene, B., (2011). Hopes and fears for science teaching: The possible selves of preservice teachers in a science education program. Journal of Science Teacher Education, 22, 491-512.

James, H. (1971). Attitude and attitude change: Its influence upon teaching behavior. Journal of Research in Science Teaching, 8, 351-355.

Kessinger, T. A. (2009). Standard one: Teaching. In C. Klecka, S. Odell, R. Houston, & R. M[c]Bee (Eds.), Visions for teacher educators (pp. 67-72). New York: Association of Teacher Educators & Rowman & Littlefield Education

Kuh, G. D. (2003). What we're learning about student engagement from NSSE: benchmarks for effective educational practices. Change: The Magazine of Higher Learning, 35, 24-32.

Lunenberg, M., & Korthagen, F. (2009). Experience, theory, and practical wisdom in teaching and teacher education. Teachers and Teaching: Theory and Practice*,* 1, 225-240.

Milne, C., & Otieno, T. (2007). Understanding engagement: Science demonstrations and emotional energy. Science Education, 91, 523-553.

Newton, J. (2010). At tale of two 'qualitys': Reflections on the quality revolution in higher education. Quality in Higher Education, 16, 51-53.

Nussbaum, J., & Novick, S. (1982). Alternative frameworks, conceptual conflict, and accommodation: toward a principled teaching strategy. Instructional Science, 11, 183-200.

Pekrun, R., & Stephens, E. J. (2010). Achievement emotions in higher education. In J. C. Smart (Ed.), Higher education: Handbook of theory and research, 25, pp. 257-306. Dordrecht, The Netherlands: Springer.

Ritchie, S. M., Tobin, K., Hudson, P., Roth, W.-M., & Mergard, V. (2011). Reproducing successful rituals in bad times: Exploring emotional interactions of a new science teacher. Science Education. 95, 745-765.

Ritchie, S. M., Tobin, K., Roth, W.-M., & Carambo, C. (2007). Transforming an academy through the enactment of collective curriculum leadership. Journal of Curriculum Studies, 39, 151-179.

Ritchie, S. M., Tobin, K., Sandhu, M., Sandhu, S., Henderson, S., & Roth, W.-M. (2013). Emotional arousal of beginning physics teacher during extended experimental investigations. Journal of Research in Science Teaching, 50, 137-161.
Roth, W.-M., & Hsu, P.-L. (2010). *Analyzing communication: Praxis of method.* Rotterdam, The Netherlands: Sense Publishers.
Roth, W.-M., Ritchie, S. R., Hudson, P. & Mergard, V. (2011). A study of laughter in science lessons. Science Education, 48, 437-458.
Roth, W.-M., & Tobin, K., (2005). Teaching together, learning together. New York: Peter Lang Publishing.
Scott, P. H., Mortimer, E. F., & Aguiar, O. G. (2006). The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. Science Education, 90, 605-631.
Schutz, P. A., Aultman, L. P., & Williams-Johnson, M. R. (2009). Educational psychology perspectives on teachers' emotions. In P. A. Schutz, & M. Zembylas (Eds.), Advances in teacher emotion research: The impact on teachers' lives (pp. 195-212). Dordrecht, The Netherlands: Springer.
Segers, M., & Dochy, F. (1996). Quality assurance in higher education: Theoretical considerations and empirical evidence. Studies in Educational Evaluation, 22, 115-137.
Sewell, W. H. Jnr. (2005). Logics of history. Social theory and social transformation. Chicago: The University Press of Chicago.
Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15, 4-14.
Sinatra, G. M., Broughton, S. H., & Lombardi, D. (2014). Emotions in science education. In R. Pekrun, & L. Linnenbrink-Garcia (Eds.), International handbook of emotions in education, (pp. 415-436). New York: Routledge.
Thoits, P. A. (1989). The sociology of emotions. Annual Review of Sociology, 15, 317-342.
Tobin, K., & Ritchie, S. M. (2012). Multi-method, multi-theoretic, multi-level research in the learning sciences. The Asia-Pacific Education Researcher, 20, 117-129.
Tobin, K., Ritchie, S. M., Hudson, P., Oakley, J., & Mergard, V. (2013). Relationships between EC and the fluency of classroom interactions. Learning Environments Research, 16, 71-89.
Trigwell, K. (2012). Relations between teacher's emotions in teaching and their approaches to teaching in higher education. Instructional Science, 40, 607-621.
Tok, S. (2011). Preservice primary education teachers' changing attitudes towards teaching: a longitudinal study. European Journal of Teacher Education, 34, 81-97.
Turner, J. H. (2007). Human emotions: A sociological theory. London: Routledge.
Watson, D., & Clark, L. A. (1994). The PANAS-X. Manual for the positive and negative affect schedule- Expanded form. Retrieved from http://www.psychology.uiowa.edu/faculty/clark/panas-x.pdf
Wertsch, J. V., & Toma, C. (1995). Discourse and learning in the classroom: A sociocultural approach. In L. P. Steffe & J. Gale, Constructivism in education (pp. 159-174). Hillsdale, NJ: Lawrence Erlbaum.
White, R., & Gunstone, R. (1992). Probing understanding. London: Falmer.